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Tracing the Impact of Non-Use of Antimicrobial Growth Promotors on Output Productivities in Danish Broiler Production

Institute of Food and Resource Economics (FOI)

Working Paper 2007/14

Tracing the Impact of Non-Use of Antimicrobial Growth Promotors on Output Productivities in Danish Broiler Production

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Abstract

The use of antimicrobial growth promoter was discontinued in the Danish poultry sector since January 1999 on the recommendations of the industry itself and the government. The aim has been to ensure consumer food safety. From the economic point of view it is expected that poultry producers will react by restructuring the input set. This paper reports the results of an investigation of the economics of use and non-use of antimicrobials as growth promoters by tracing the development of broiler output elasticities with respect to inputs and technical change using a production function. We used aggregated panel data from 1994 to 2004 for broiler farms classified as small, medium and large. Our findings suggest that the component of feed in scale elasticities through the period declined, while that of chick stock increased as a result of a decreasing mortality rate and increasing growth rate. The implication is that discontinuous use of antimicrobial growth promoters has no effect on broiler production.

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Preface

This Working Paper is among a series of research projects aimed at increasing the knowledge of the impact of discontinuous use of Antimicrobial Growth promoters on the economic efficiency of livestock production in Denmark. The Working Paper complements other projects related to the economics of food safety as well as animal health. The basic focus of the paper is to identify how producers react to the ban on use of antimicrobial growth promoters and hence the policy implications of the ban.

The working paper has been written by assistant professor Lartey Godwin Lawson in corroboration with project researcher Vibeke F. Jensen from the National Veterinary Institute, Technical University of Denmark and Associate Professor Lars Otto from the Institute of Food and Resource Economics, University of Copenhagen.

The working paper has been reviewed by Research Director Mogens Lund.

Mogens Lund
Division of Production and Technology
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Copenhagen, November 2007

1. Introduction

The ban on the use of antimicrobial growth promoters in general during the period 1995-2000 in Denmark, and subsequently in the EU as a whole, was primarily motivated by a concern for food safety and human health; i.e. to avoid the potential transfer of unwanted residue and bacteria resistance. This decision, however, has other implications for animal health conditions and therefore farm economics in general. Previous studies have shown that the use of antimicrobial growth promoters as a feed additive over time have some positive animal health effects, such as lowering mortality and morbidity rates that could result from bacteria infections, and the improvement in feed efficiency (WHO, 2002; Wierup, 2001). The improvements in feed efficiency may lower production costs, increase output, and therefore induce lower prices for consumers (Mathews. 2001). The health promoting effects of antimicrobial growth promoters has led some scholars to suggest that in the event of a ban, the therapeutic use of antimicrobials would increase. This would potentially undermine the prevention of possible hazards to human health in cases of zoonosis and other transfers of bacterial resistance.

Debates for and against the ban have many viewpoints. Coffman et al. (1999) provided an extensive account of the use of drugs with special reference to antimicrobials in livestock production. Their study suggested although resistance was low, there is the link between the use of antimicrobials in livestock and the incidence of bacterial resistance; i.e. the drugs and human diseases.

Referring to the work of others, Coffman et al. (1999) reported that antimicrobial growth promoters are most effective in animals under stress, as result of poor nutrition and sanitation. Hayes, Jensen and Fabiosa (2002) later reported the same view. Coffman el al. (1999) suggested that some livestock producers (e.g. antimicrobial growth promoter free producers) might actually benefit from a ban. This could be the case if the cost of production without antimicrobial growth promoters is passed on to consumers in the form of higher prices. Consumers would thereby bear the cost of a ban (Hayes et al., 2001 and Mathews 2001).

Previous studies of the effect of a ban on antimicrobial growth promoters have focused on consumer and producer gains (Hayes et al., 2001 and Mathews 2001). These studies have suggested that the consumers suffered losses as a result of anticipated high prices while the impact on producers has been mixed. Wade and Barkley's (1992) study of the pig sector also suggested that producers would gain as result of high consumer prices. On the other hand, Hayes et al. (2001) and Mathews (2001) suggest that producers would experience losses due to producer costs being higher than the eventual consumer price increases. The studies have, however, exhibited distinct unawareness of the eventual change in producer behaviour or of the producer decision-making process in response to a ban on antimicrobial growth promoters.

The aim of this study is to identify the change in producer behaviour or in the producer decision-making process and evaluate the impact of the ban on use of antimicrobial growth promoters on economic efficiency of broiler production. Specifically, we estimate the output elasticities with respect to variable inputs over time and make inference on whether the ban has altered the productivity parameters for broiler producers. Using long period data, we are able to evaluate economic efficiency and substitutability of inputs during the pre-post period of the ban and the impact of technical change. Thus, in essence we evaluate how broiler producers adjust their inputs in order to accommodate the anticipated cost increases for not using the antimicrobial growth promoter technology.

The rest of the paper develops as follows: The next section provides information on the issue of resistance and the use of antimicrobials in poultry and broiler production in Denmark. The sections on the analytical methodology and data; results and the discussion, and concluding remarks follow in that order.

2. Resistance and the use of antimicrobial in the Danish poultry sector

The use of antimicrobials in the poultry sector can be traced by three different purposes of use: (1) therapeutically as treatment against bacteria infection, (2) preventively as measure against a parasitic infection, coccidiosis, and (3) as growth promoters to increase feed efficiency, which is due to preventing different types of bacteria infection.

Prior to the year 1999, when the use of antimicrobial growth promoters was discontinued in the poultry sector, the antimicrobial resistance in broilers and broiler meat was high for some antimicrobials and bacteria. For example, resistance in *Enterococcus faecium* to the antimicrobials tetracycline and erythromycin were 20% and 76%, respectively and the resistance to growth promoters was 80-100%, decreasing subsequent to the ban (DANMAP 1997, DANMAP 2005).

An estimated 5 metric tons of antimicrobial was used as growth promoter in Danish poultry in 1998, i.e. 26mg/poultry meat before the ban. Prior to the year 2000, the amount of antimicrobial used for therapy was unknown. However, during 2001-2005, the annual use of therapeutic antimicrobials for poultry in Denmark varied between 0.4 and 0.6 metric tons and the consumption for broilers in 2005 was 138 kg, corresponding to 0.77 mg/kg broiler meat. The use of coccidiostats, which include ionophores that have antibacterial effect, against the volatile coccidial infection in poultry was in 1990 117 mg/kg broiler meat and reached the peak of 142 mg/kg broiler meat in 1999. Since then its use in broiler production has in average decreased by 45 % during the period 2000 to 2004 and more specifically decreased by 49% in 2004. Thus, therapeutic antimicrobial use has remained at a very low level and the use of coccidiostat has decreased relative to the level in 1990 after the discontinuation of antimicrobial growth promoters in Denmark.

Leading actors within the broiler-production industry have advanced arguments against the ban on the grounds of mortality and morbidity caused by necrotic enteritis (a poultry disease). It has been anticipated that necrotic enteritis would ensue as a result of the discontinued use of antimicrobial growth promoters. In Sweden, outbreaks were prevented by the continuous use of prescription in-feed antimicrobials in the first two years of the ban. Thereafter, necrotic enteritis was prevented by different management procedures with treatment only in cases of outbreaks (Wierup, 2001). In Denmark, the reported flock incidence of necrotic enteritis increased (from one-two yearly outbreaks to 25 cases in a population of >1700 flocks) the year after the discontinuation of antimicrobial growth promoters in 1999. Some scholars have, however, argued that the increase might have arisen from an increased willingness to report, due to the establishment of an industry fund to compensate producers for any losses associated with necrotic enteritis following the discontinuation (Tornøe, 2002). With these caveats in mind, it is relevant to evaluate how broiler producers have reacted to the discontinuation of the use of antimicrobial growth promoter technology.

3. Analytical methods and data

Analytical methods

We formulated and estimated a parametric production function model to evaluate the production structure, using a data set spanning the years 1994 to 2004. The analysed production function is a Cobb-Douglas one, where input elasticities are linear functions of time. The model specification and estimation follows that of Heshmati, Kumbhakar and Hjalmarsson (1995). It differs from Heshmati and others by not including fixed capital inputs because of the lack of information. The choice of the functional form specification is due to the limited number of observations ($n*t = 33$). The model specification is as follows:

$$
\begin{aligned}
\ln Y_{it} &= \mu_0 + \sum_{j=1} \beta_j \ln X_{jit} + \beta_t t_i \\
&\quad + \sum_{j=1} \beta_{tj} t_i \ln X_{jit} + \frac{1}{2}\beta_{tt} t^2 + \mu_i + e_{it} \\
&\quad (i = small, medium, large\ farm\ groups) \\
&\quad (t = 1994, \cdots, 2004) \\
&\quad (j = chick, feed, sundry\ inputs)
\end{aligned}
\qquad [1]
$$

where Y_{it} is broiler output per production unit group i in time t,; X_j are inputs; the time trend, t, and its quadratic term represents the technical change; μ_i is the group specific fixed effects of the three production unit groups and μ_0 is the intercept. The small production unit represents farms with a broiler capacity of less than 25 000 birds per rotation, the capacity of the medium farm group is 25 000 to 100 000 birds, while the large farm group has a capacity of over 100 000 birds per rotation (see for example DPC, 2004, p. 74); e_{it} is the error term, and is $N(0,\sigma^2)$.

In the formulation [1], the output elasticities vary over time and reflect the changes in the production structure. These output elasticities are also shares of input cost to total revenue under competitive market conditions. In addition, farm effects are directly extracted from eventual inefficiency in the production system. The technical change represented by time can be decomposed into pure time effect and a biased part associated with inputs. The model formulation is used to study the trend in output productivities with respect to inputs, elasticities and technical change over time, in order to identify an eventual substitution during the post ban period. From the production function in equation [1] the output elasticities, ε, with respect to inputs is given by:

$$\varepsilon_i = \frac{\partial \ln Y}{\partial \ln X} = \beta_j + \beta_{ij} t \qquad [2]$$

The rate of technical change (TC) is given by:

$$\varepsilon_{TC} = \frac{\partial \ln Y}{\partial t} = \beta_t + \beta_{tt} t + \sum_j \beta_{tj} \ln X_{jit} \qquad [3]$$

If the technical change is not neutral (i.e. $\beta_{tj} \neq 0$) then the bias for technical change is:

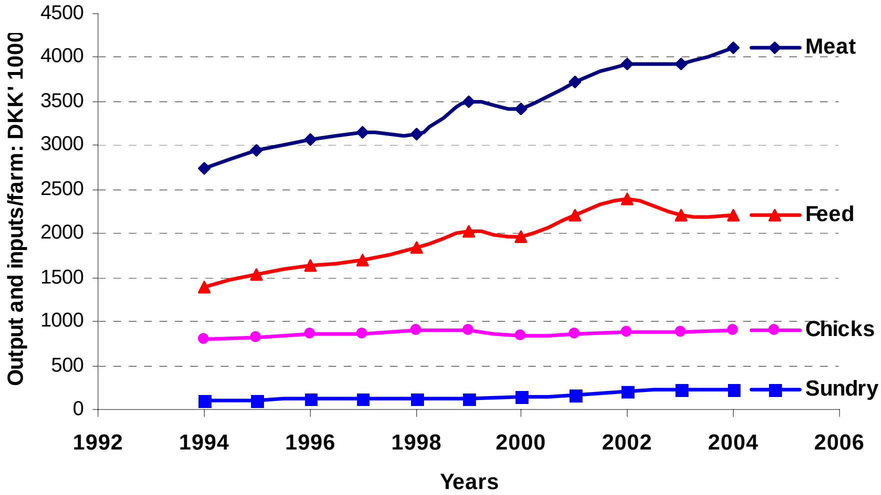
$$B_{jt} = \frac{\partial \ln X}{\partial t} = \frac{\beta_{tj}}{\varepsilon_j} + \varepsilon_{TC} \qquad [4]$$

Technical change is input, *j,* using if $B_{jt} > 0$ and input, *j*, saving if $B_{jt} < 0$.

Data

The data for the analysis comes from the annual reports of the Danish Poultry Council (DPC), covering the years 1994-2004. The data represents nearly all Danish broiler producing farms (between 333 and 277 for 1994 and 2004). The data used for the analysis is information based on the aggregate of farm unit groups of small, medium and large, farms based on the size of broiler production per rotation. The number of farms units in each group through the period is on average 46, 202 and 57 for small, medium and large farms, respectively. The averages for output and inputs are plotted for the period 1994 through 2004 in Figure 1.

Figure 1. Averages of meat output, chick stock, feed and sundry inputs, 1994-2004



The output, Y, is the total income from kilo broiler produced and measured in the Danish currency, DKK, which are converted to the year 2000 prices, using the producer price index for poultry. The input variables, X_j, for chicks, feed and sundries are total expenditures in the Danish currency, converted into the year 2000 prices using livestock feed cost price index for feed and livestock and requisites cost price index for chick and sundry. The time variable t, is coded 0, 1, 2, 3, …, 10 for 1994 through 2004. The chosen parameterisation of time allows for estimating elasticities at the average point in 1994. This implies that output elasticities with respect to inputs for subsequent years can be compared to the corresponding 1994 estimates, which is a base year prior to the first ban imposed on the use of antimicrobial growth promoters in 1995. The total expenditure for sundry includes among other items those for veterinary services, medication, cleaning, water, energy and solutions used for the disinfections of broiler houses.

4. Results

The test that the estimated model error-term, e_{it}, in equation [1] is $N(0,\sigma^2)$ was not rejected. The parameter estimates for the production function analysis are presented in Table 1.

Table 1. Production function: least square parameter estimates

Variables	Symbol	Parameter Estimates	Standard error	t_value	Significance Level
Constant (Medium_farms)	μ_0	2.009	1.001	2.01	0.057
Chick stock	β_1	-0.504	0.376	-1.34	0.194
Feed	β_2	1.363	0.387	3.52	0.002
Sundry	β_3	0.066	0.117	0.57	0.576
Time	β_t	-0.020	0.046	-0.44	0.662
Time^2	β_{tt}	0.006	0.002	3.00	0.005
Time x chick stock	β_{t1}	0.101	0.047	2.15	0.043
Time x feed	β_{t2}	-0.102	0.049	-2.10	0.048
Time x sundry	β_{t3}	0.002	0.019	0.13	0.901
Small_farms	μ_1	-0.236	0.126	-1.87	0.075
Large_farms	μ_3	-0.024	0.019	-1.25	0.226
Number of observations	33				

Except for sundry input all the parameter estimates are associated with a level of significance. The fixed effect of the group of large farms is on average not significantly different from medium sized farms, which is captured by the intercept. The estimated value of -0.024 for large farms suggests that this group produces on average 98% ($e^{-0.024}$) of what is produced by medium sized farms. This is despite the fact that the large producing group accounts for only 19% of producers. The group of small farms with 15% of producers and a production size of less than 25 000 birds per rotation, on average differs moderately from the medium and the large farm groups. The estimate of -0.236 suggests they produce 79% of the production by the medium sized farms. The coefficients β_1, β_2 and β_3 are output elasticities with respect to the inputs chick stock, feed and sundry in 1994. As shown, it is mainly the feed input that determines the output productivity in 1994. The estimated yearly output elasticities with respect to inputs, technical change and their biases are provided in Table 2.

Table 2. Output elasticities (chick, feed and sundry), scale, technical change (TC) and input biases by year

Year	Chick	Feed	Sundry	Scale	TC	Pure TC	Non-Pure-TC	Chick-Biases*	Feed-Biases	Sundry-Biases
1994	-0.504	1.363	0.066	0.926	-0.052	-0.020	-0.031	-	-0.127	-0.016
1995	-0.403	1.261	0.069	0.928	-0.046	-0.009	-0.038	-	-0.127	-0.011
1996	-0.301	1.160	0.071	0.929	-0.037	0.003	-0.040	-	-0.124	-0.003
1997	-0.200	1.058	0.074	0.931	-0.028	0.015	-0.042	-	-0.124	0.005
1998	-0.099	0.956	0.076	0.933	-0.020	0.026	-0.046	-	-0.127	0.012
1999	0.002	0.854	0.078	0.935	-0.017	0.038	-0.055	-	-0.136	0.014
2000	0.103	0.752	0.081	0.937	-0.011	0.050	-0.061	0.968	-0.146	0.019
2001	0.205	0.650	0.083	0.938	-0.007	0.062	-0.069	0.488	-0.164	0.022
2002	0.306	0.549	0.086	0.940	0.000	0.073	-0.073	0.331	-0.185	0.028
2003	0.407	0.447	0.088	0.942	0.023	0.085	-0.062	0.271	-0.205	0.050
2004	0.508	0.345	0.091	0.944	0.035	0.097	-0.062	0.234	-0.261	0.061

* Non-applicable values due the corresponding negative elasticities.

In Table 2, it can be seen that output elasticity with respect to feed input decreases from 1.36 in 1994 to 0.34 in 2004 (Table 2, column 3). However, the output elasticity with respect to chick stock (column 2) is increasing as well as that for the sundry input. The output elasticity with respect to chick stock is negative for the first 5 years, and was not significantly different from zero for 1994 through 2001. However, estimates for 2002 through 2004 were significantly different from zero. This suggests that 3 years after the discontinuous use of antimicrobial growth promoters in 1995 through 1999, farmers turn to use improved quality chick stock. Hence suggesting that input substitution between feed and chick stock inputs exists.

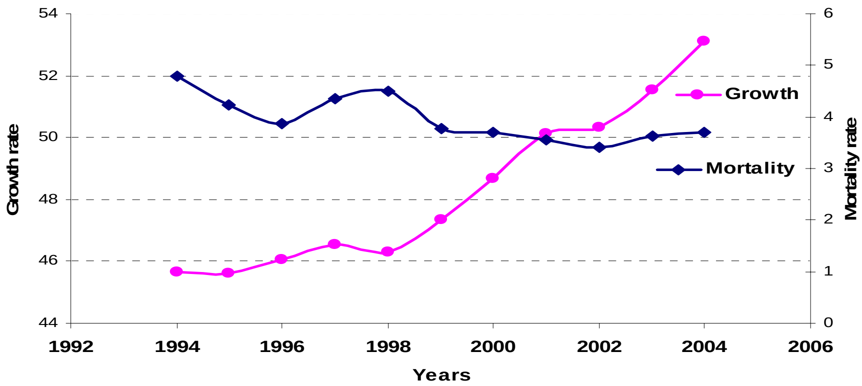
The substitution effect between feed and chick input is also reflected by the technical change biases for the input variables from the year 2000 (last 3 columns). While the technical change biases for feed are input saving, that of chick stock is input using. The sundry input bias is input using during the period 1994 through 1996 and then input using during the period 1997 through 2004, which further suggests the increased attention on sanitation after the ban in 1995. The pure-technical change rose from 2% in 1994 to 9.7% in 2004, which suggests that since 1994, pure-technical change seems to capture the positive effects of other factors that were not included in the model. An example is the improved breed of the chick stock.

5. Discussion and concluding remarks

We have investigated the impact of the discontinuation of the use of antimicrobial growth promoters by estimating a Cobb-Douglas production function with input coefficients being a function of time using aggregated data. We found that the elasticity of output with respect to feed input decreased at a constant rate of 0.10 percent points through the given time period. The decrease was mainly substituted by the increase in output elasticity with respect to chick stock input and with a minor contribution from output elasticity with respect to sundry input.

Questions can be raised whether the development of the output elasticities with respect to feed and chick stock inputs has been due to the non use of the antimicrobial growth promoter technology. But from figure 2 the efficiency of production evaluated by the development of mortality and growth rates of chick stock, suggests that farms can maintain their production level without the use of antimicrobial growth promoters but by increasing sundry input. Sundry inputs, among other factors represent an improvement in hygienic and sanitation management. Since the late 1990's the focus on hygiene, sanitation and the prevention of bacteria infection in broiler production increased, mainly to counteract the high prevalence of salmonella infection.

Figure 2. Yearly average growth and mortality rates of broiler birds: 1994-2004



Furthermore, the growth rate of chick stock increased due to the use of improved breeding stock, which induced high feed conversion ratio i.e. improved feed utilisation. The choice and the distribution of breeding stocks since 1994 changed during the period 1999 through 2001. The use of a dominant breed dwindled at the expense of a specific breed. This specific breed, which was the less used earlier eventually replaced the most dominant breed in use during 1994 through 2002 due to the improvement in its growth rate (DPC, 2004). The improvement in breeding stock is captured by the pure technical change (Table2).

The scale elasticity measure averages about 0.94, suggesting that the poultry sector is on average producing at a decreasing return to scale. However, it should noted that this could be due to our model specification, which did not include fixed capital input. Although we lack information on capital input in our model, it is believed that the model reflected the impact of use and non-use of antimicrobial growth promoters. This is due to the fact that antimicrobial growth promoters are directly related to the feeding regime.

A previous Danish study, (Emborg *et al.*, 2001), using data from the early post-discontinuation period, investigated the effects of the discontinuous use of antimicrobial growth promoters by broiler producers. The results of their statistical analysis suggested that the discontinuous use of antimicrobial growth promoters had a negligible reduction in feed conversion ratio and showed no change in mortality rate and kilogram broiler produced per square meter. We found that the role of feed input in scale elasticity is decreasing and the purchased chick stock input is increasing. Thus, coupled with our findings, the decrease in mortality rate and the increased growth rate after the ban, indirectly suggests that the feed conversion ratio (feed efficiency) is improving without the use of antimicrobial growth promoters. The results indicate that for the poultry industry, the pre-ban harboured fear about an increase in mortality and a reduction in output was not substantiated.

Other researchers, Hayes et al. (2001), Mathews (2001) and Hayes, Jensen and Fabiosa (2002) in investigating the impact of an eventual ban on the use antimicrobial growth promoters emphasised the estimation of what it would cost producers and consumers. The information provided by their work is relevant for monetary quantification of the impact of an eventual ban for producers and society. Our study is less comparable to theirs because our focus has been on producer behaviour or decision-making expressed by the economic parameters of elasticities, which we believe express producers adjustment to not using antimicrobial growth promoters.

Our study therefore complements the previous studies by evaluating and providing specific knowledge about the production technology for a longer period before and after the complete discontinuation of the use of antimicrobial growth promoters. For the producers in countries where the ban is still under debate, the results provide useful information on the response of Danish producers as reflected in the estimated model. In the Danish case, producers increased the productivity of chick input through decreasing mortality by increasing the hygienic and sanitation management of broilers, which provided the basis for efficient transformation feed intake with subsequent increasing growth rates. The sum effect is the avoidance of input costs attributed to the use of antimicrobial growth promoters.

In conclusion, this study demonstrates that it is possible to avoid the use of antimicrobial growth promoters in broiler production without experiencing the anticipated negative impacts.

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